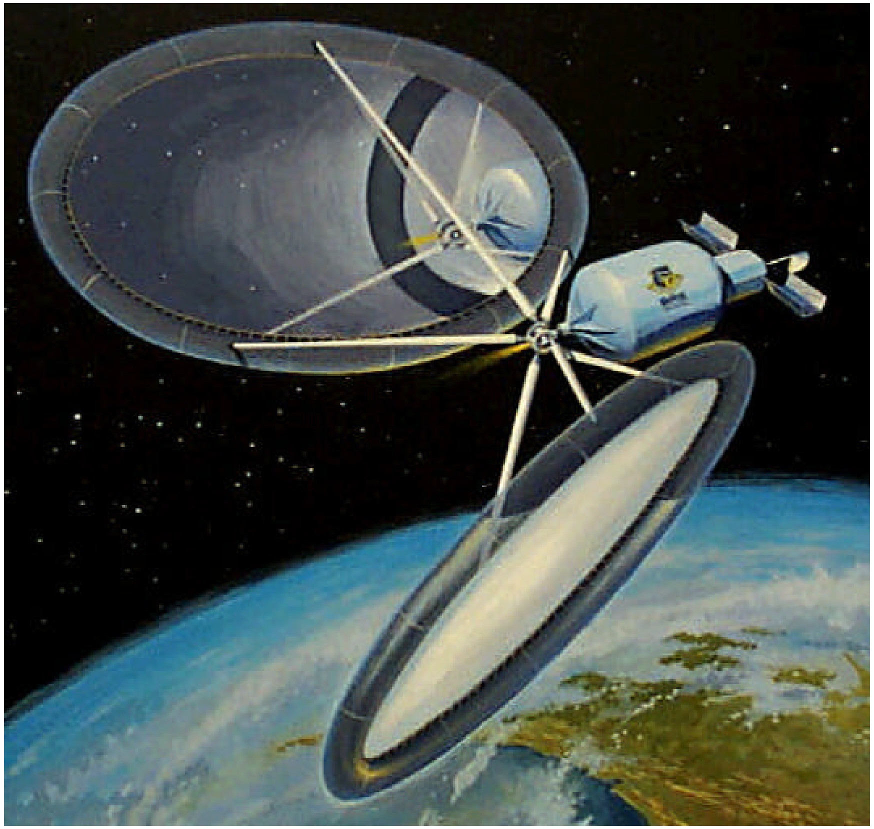
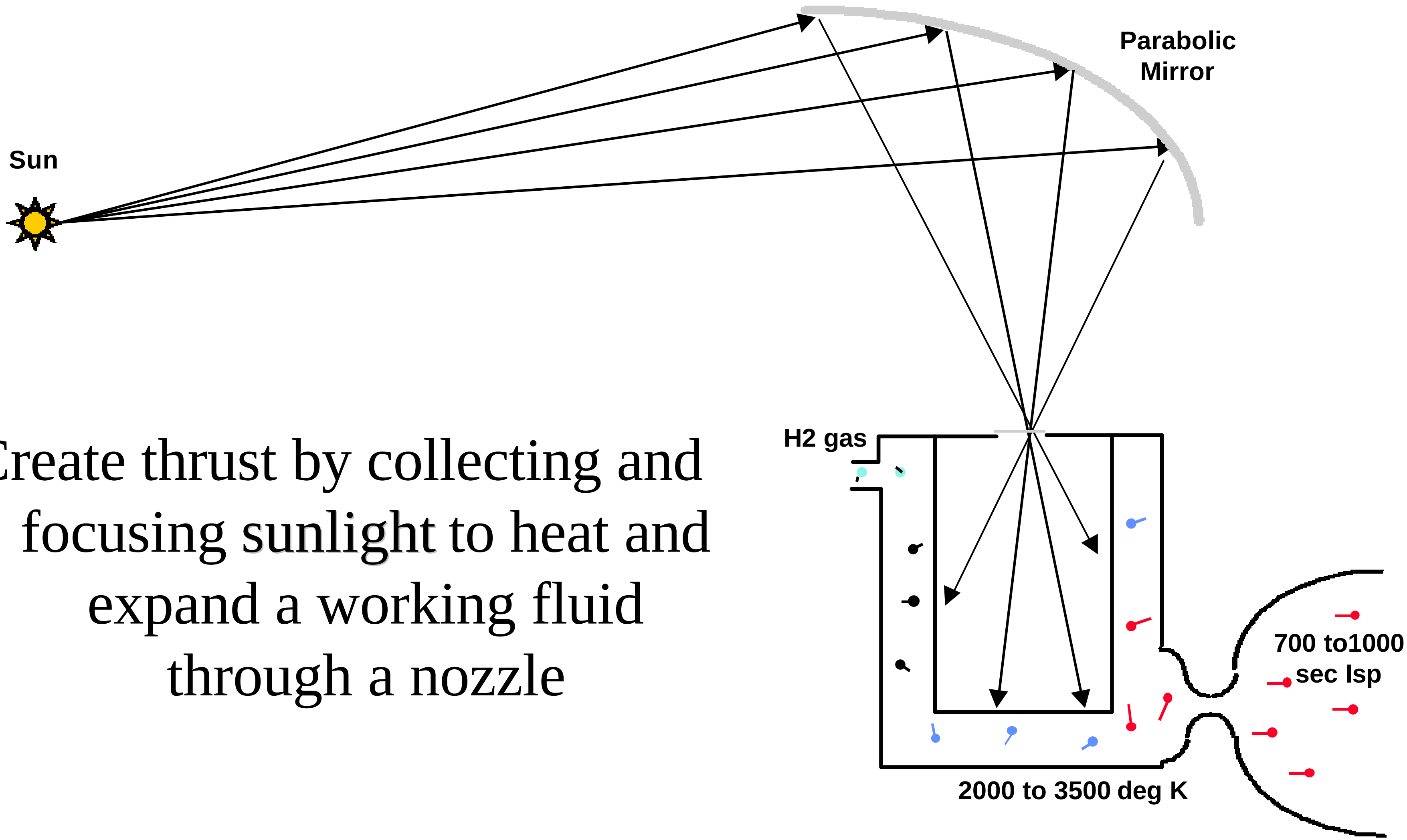
SOLAR ROCKET PROPULSION
Ground and Space Technology Demonstration

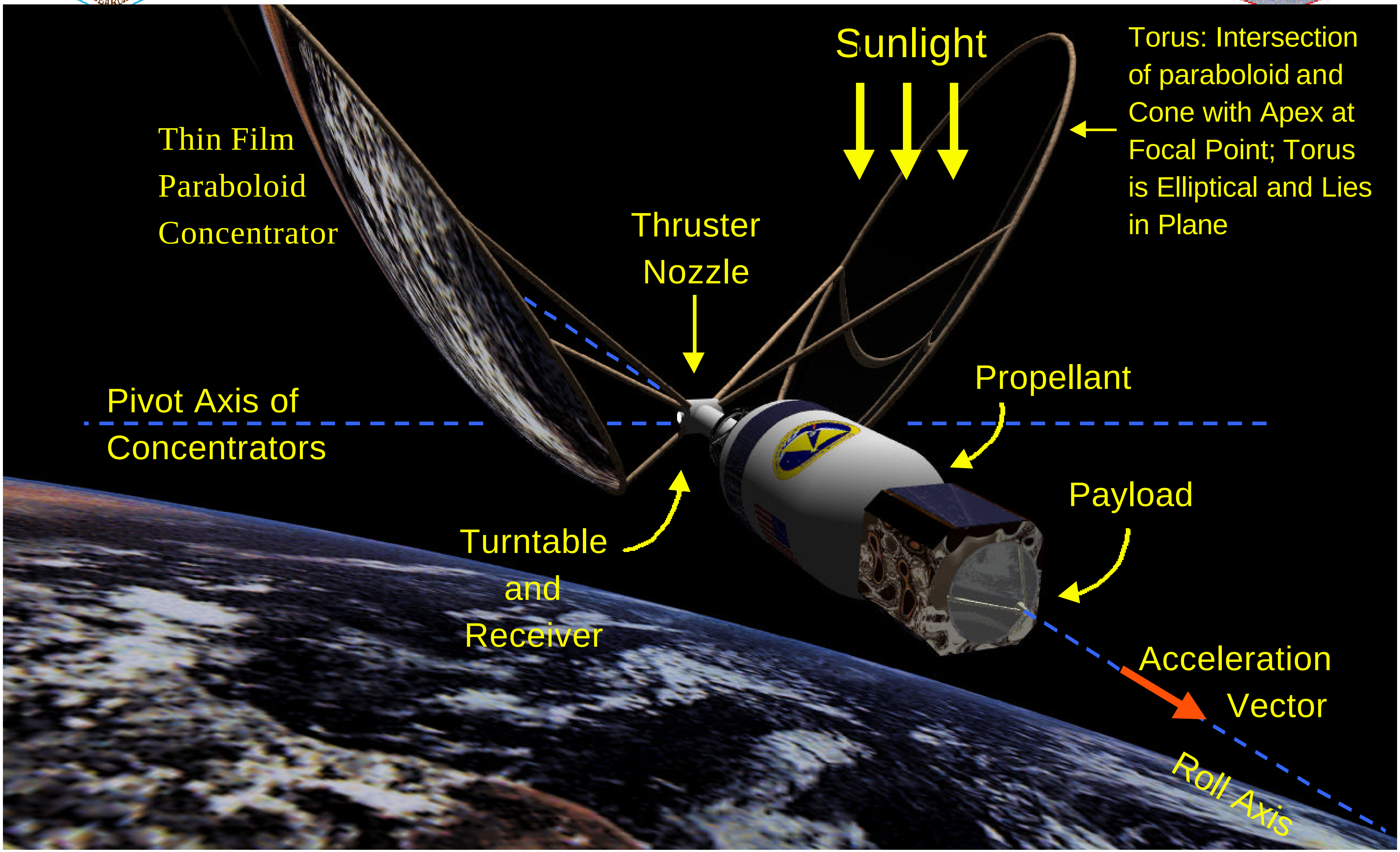
Dr. Michael Holmes, AFRL/PRSS

Solar Thermal Propulsion Concept



Create thrust by collecting and focusing sunlight to heat and expand a working fluid through a nozzle

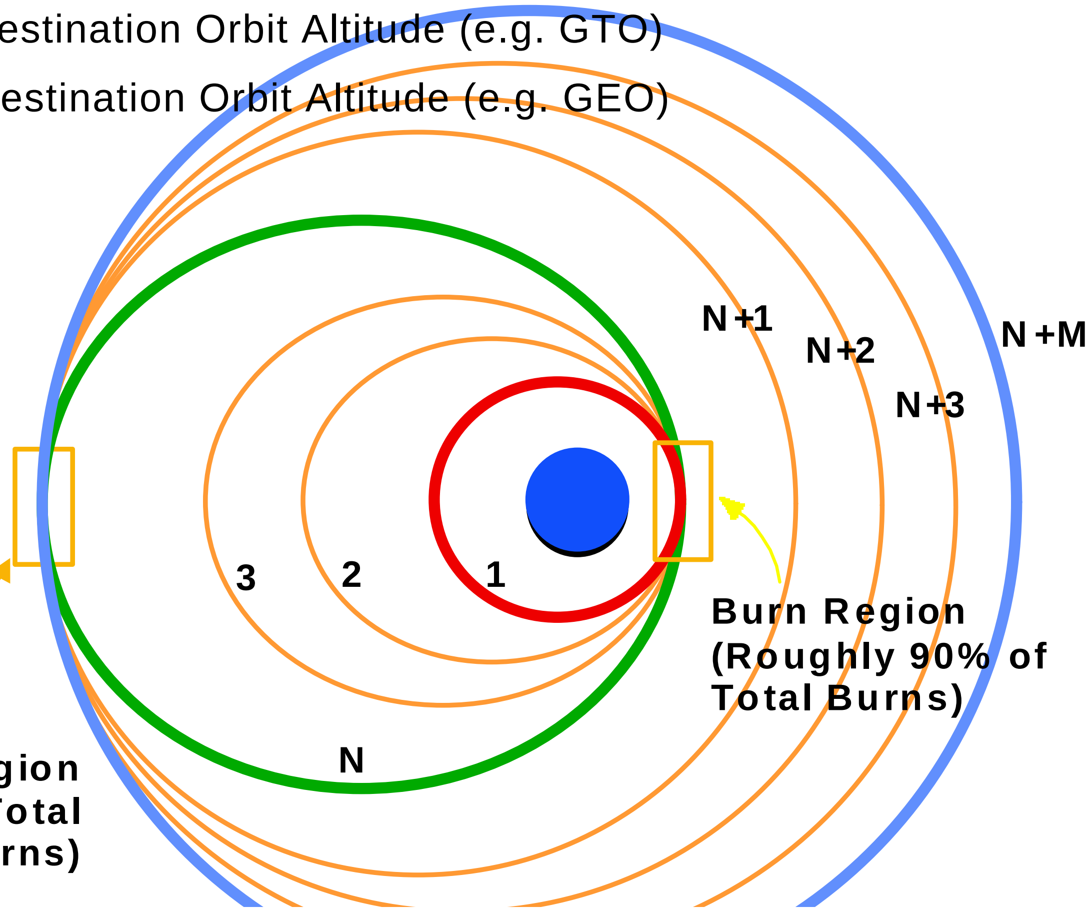
Solar-Thermal System Concept



Solar Thermal Propulsion Orbit Transfer Scenario

- Maximum Delta V Thru Multi-Burn Transfer
- Solar Thermal OTV to LEO by Ground Launch
- N Perigee Burns to Raise Apogee to Destination Orbit Altitude (e.g. GTO)
- M Apogee Burns to Raise Perigee to Destination Orbit Altitude (e.g. GEO)

- Trip Time = Sum of N+M Orbit Periods
- Higher Thrust Reduces N+M
  - Requires More Power, or
  - Reduces Delta V
- Longer Burns Reduces N+M
  - Can Decrease Delta V by Gravity Losses
- N+M=2 for Chemical Thruster
- N+M~200 for Solar Propulsion



STP Doubles Payload in Reasonable Trip Time From LEO

Solar Propulsion
IHPRPT Goals

GOALS	BASELINE	PHASE I GOAL	PHASE II GOAL	PHASE III GOAL
Isp	720 sec	792 sec 10 %	828 sec 15 %	864 sec 20 %
Mass Fraction R_m	.66	.696 5%	.722 9%	.749 13%
Dry Mass Reduction		15%	25%	35%

Mission : LEO to GEO (250nm at 28deg) ~30day

Foam Mandrel
10/29/99

Foam Mandrel on Milling Machine at NASA MSFC 10/27/99

Foam Rough Cut on 10/29/99

Flight Scale Concentrator (FSC)

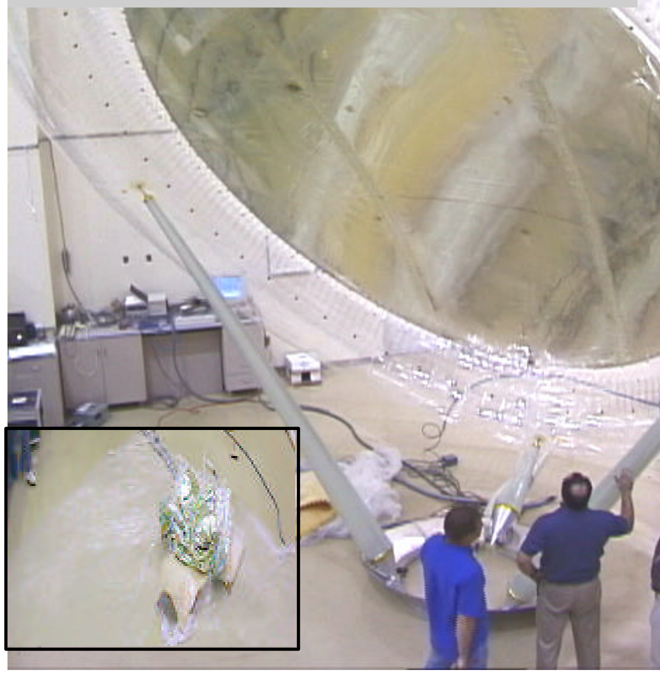
- FSC Mandrel Machined and Measured (Jan 00)
  - SRS Modeled and Generated CNC Machining Code
  - NASA MSFC Machined Mandrel
  - FSC-2 Using Foam Mandrel With Teflon Coating
- FSC-1 Fabricated (May 00)
- Method Developed to Deposit, Cure, and Release Film on Foam Mandrel
- FSC-2 (Optical Quality) Currently Being Fabricated

FSC-1

Concentrator Deployment Repeatability Demonstrated in IT-4 &5

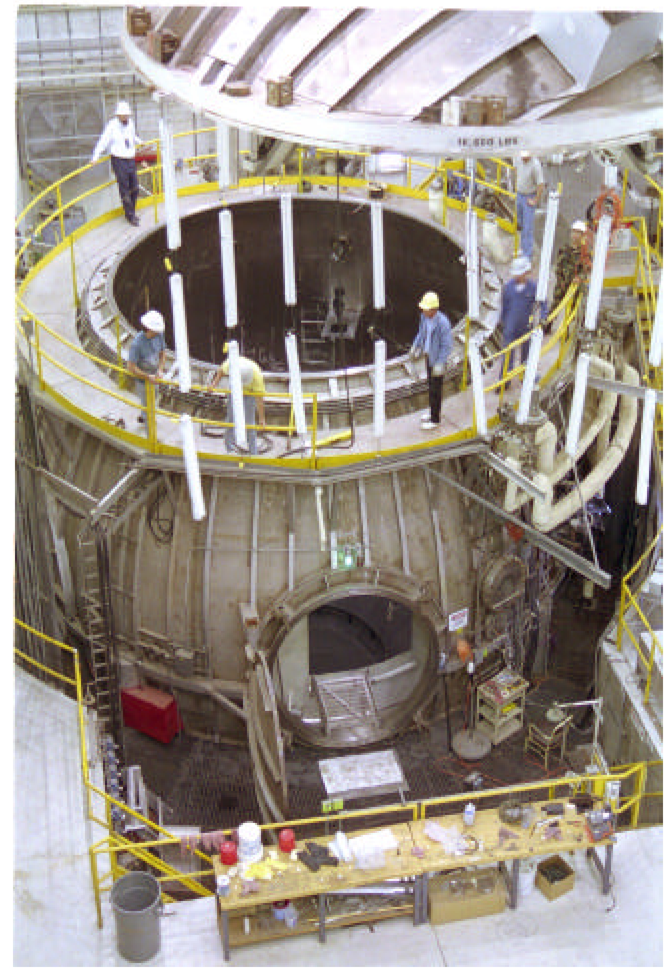
- Deployment fold pattern / packaging concept verified
- Measured< 0.5 inches variation in global geometry over 4 deployments
- No difference in global geometry observed between ambient pressure and vacuum (10^{-6} torr) deployment

Deployment Video:
http://www.stg.srs.com/aerospace.htm



Flight Scale Concentrator Ambient Deployment

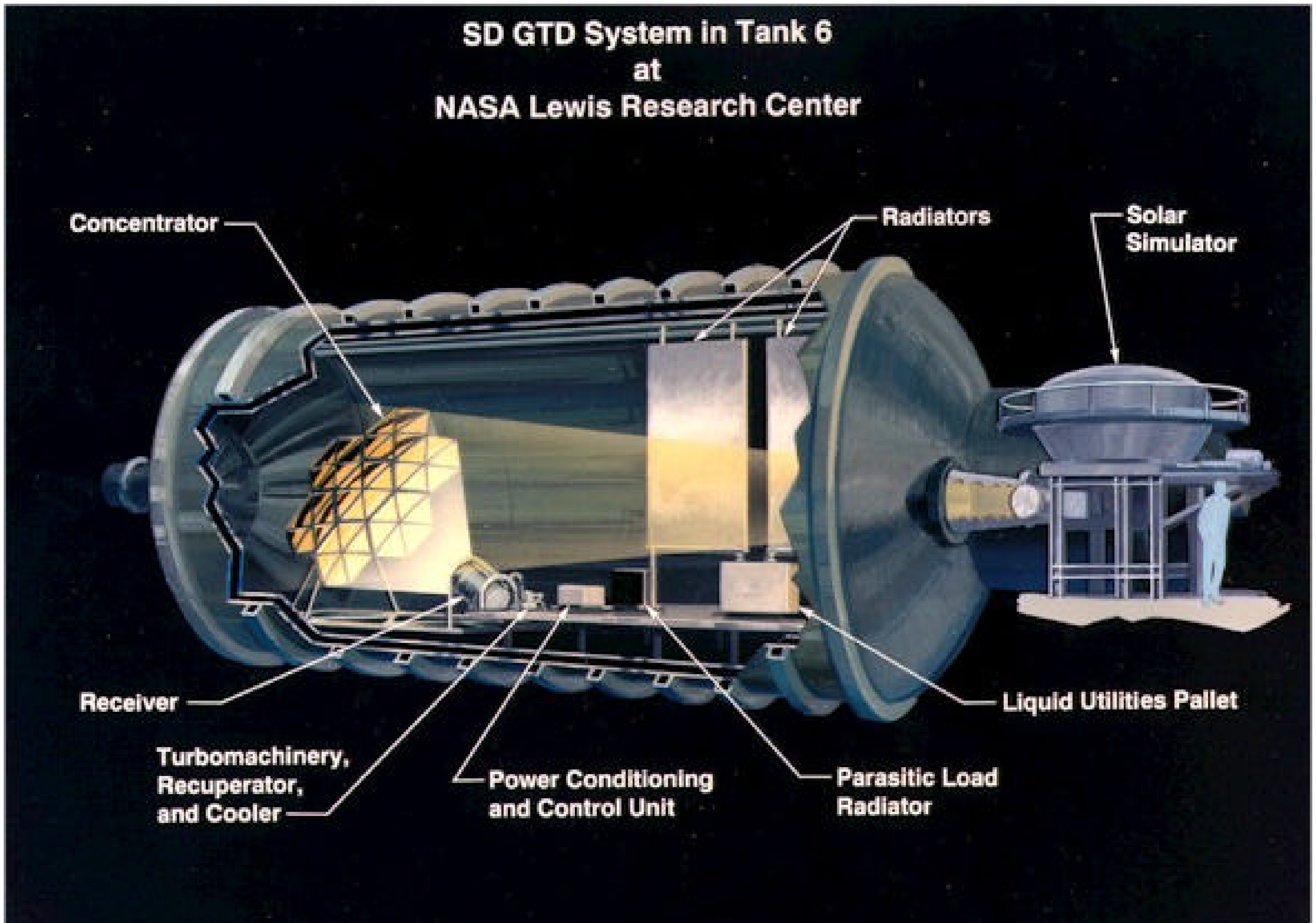
Flight Scale Concentrator inside SPEF Chamber



AFRL's Space Environmental Test Facility

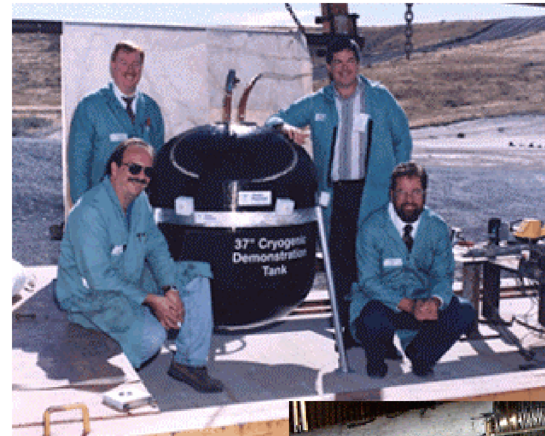
TA-1 Tank 6 Apparatus Thermal Vacuum Testing

- NASA GRC Tank 6 Simulates Space Thermal Environment
- Concentrator Shape and Position Verified under Mission Eclipse Cycling



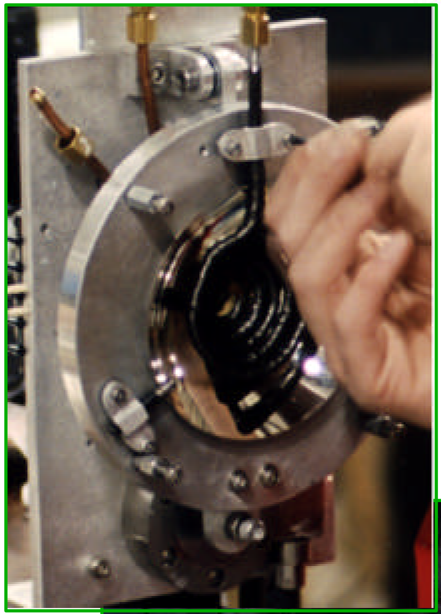
Propellant Management System Experiment

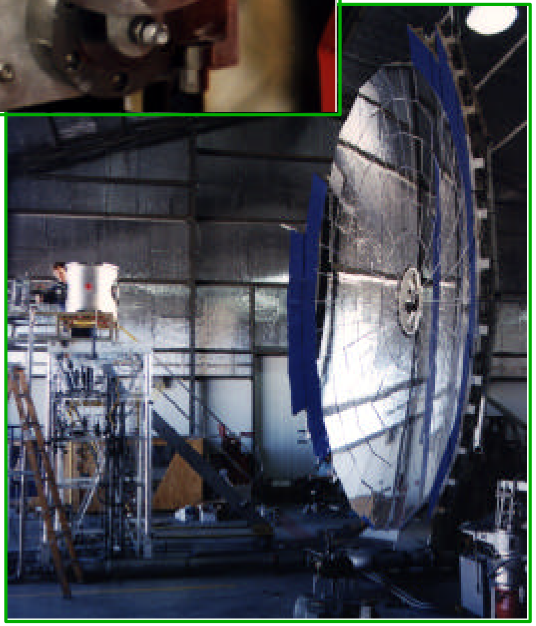
- New Approach to Cryogenic Propellant Management
  - Control Tank Pressure by,
    - Remove Vapor -> Lower Pressure
    - Remove Liquid -> Raise Pressure
    - Acceleration Pulls Liquid to "Bottom" of Tank
  - Advantages
    - Large Heater Eliminated
    - Thermodynamic Vent System (TVS) Eliminated
    - Mixer Eliminated
    - Simplified Control Software
    - Lower Pressure Tank -> Lower Weight
  - Preliminary Results Very Good
  - SRS and MSFC have Models and will Compare to Data
- Thiokol Composite Tank Reduces Tank Fraction



Solar-Thermal Propulsion
Thiokol/SRS Thruster Design

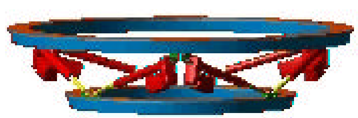
- Well Tuned to Input Light Distribution
- Beam Fractionating
  - Highest Intensity at Hottest Propellant
  - Pointing Error Tolerant
  - Lowest Intensity at Coolest Propellant
- Optical Blackbody Cavity
  - Minimize Insulation
  - Secondary Mirror Cooled by Incoming Propellant
- Capable of Meeting Phase II IHPRPT Goals
- Technologies Extensible to Phase III
- Proven in Short Duration Testing (<10 hours)
- Working on 3-D Model





First Ever Integrated Test Of Solar Thermal Propulsion System This Summer

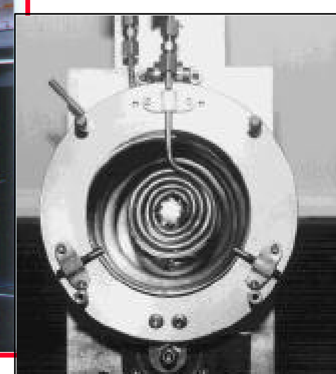
- Concentrator will track sun
- Matches flux profile but not power of space system
- Thruster in vacuum chamber
- 792 sec Isp will be shown by analytical correction of:
    - 25% atmospheric loss
    - 10% window loss



Hexapod Focusing Model

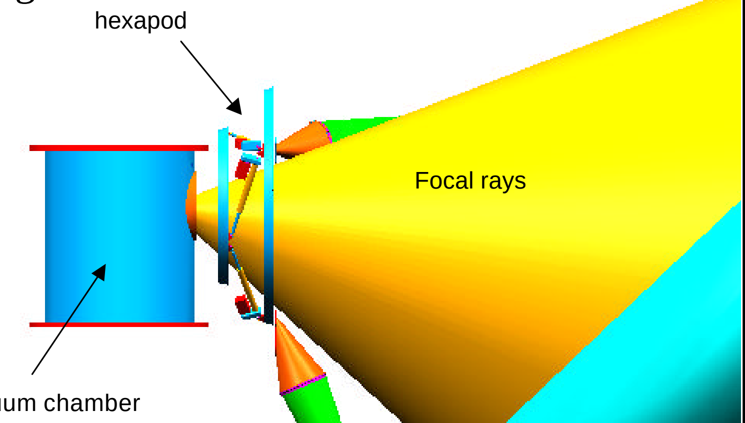
Hexapod Focusing Test Bed

Concentrator Assembly



Direct Gain Engine

Integrated Test Hardware Solid Model



Key Assumptions
Solar Thermal

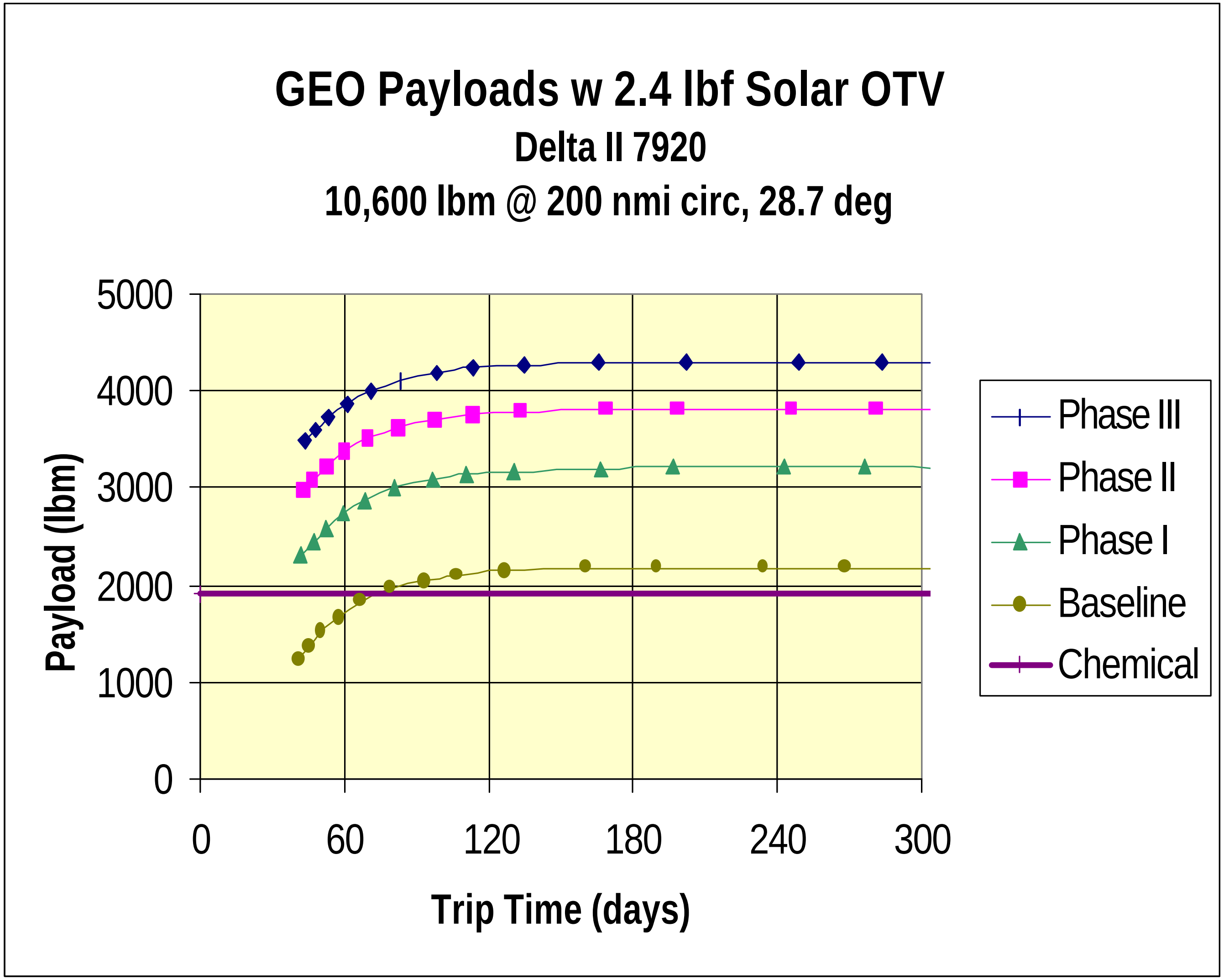
- Liquid Hydrogen
  - LH2 stored at 45 psi as saturated liquid
  - MLI + thermodynamic feed prevent venting
  - 6% residual
- Direct gain concept
  - No thermal storage
  - Large inflatable reflectors
  - Capable of meeting IHPRPT Isp goals

Solar Thermal Study Assumptions

Parameter	Baseline	Phase I	Phase II	Phase III	
Isp	720	792	828	864	sec
Engine efficiency	0.3	0.35	0.4	0.45	
Eng specific mass	4	1	0.9	0.8	kg/Nt
Concentrator eff.	0.6	0.6	0.75	0.9	
Conc specific mass	0.0014	0.001	0.00085	0.0007	kg/Wsun
Tankage fraction	0.29	0.265	0.23	0.2	

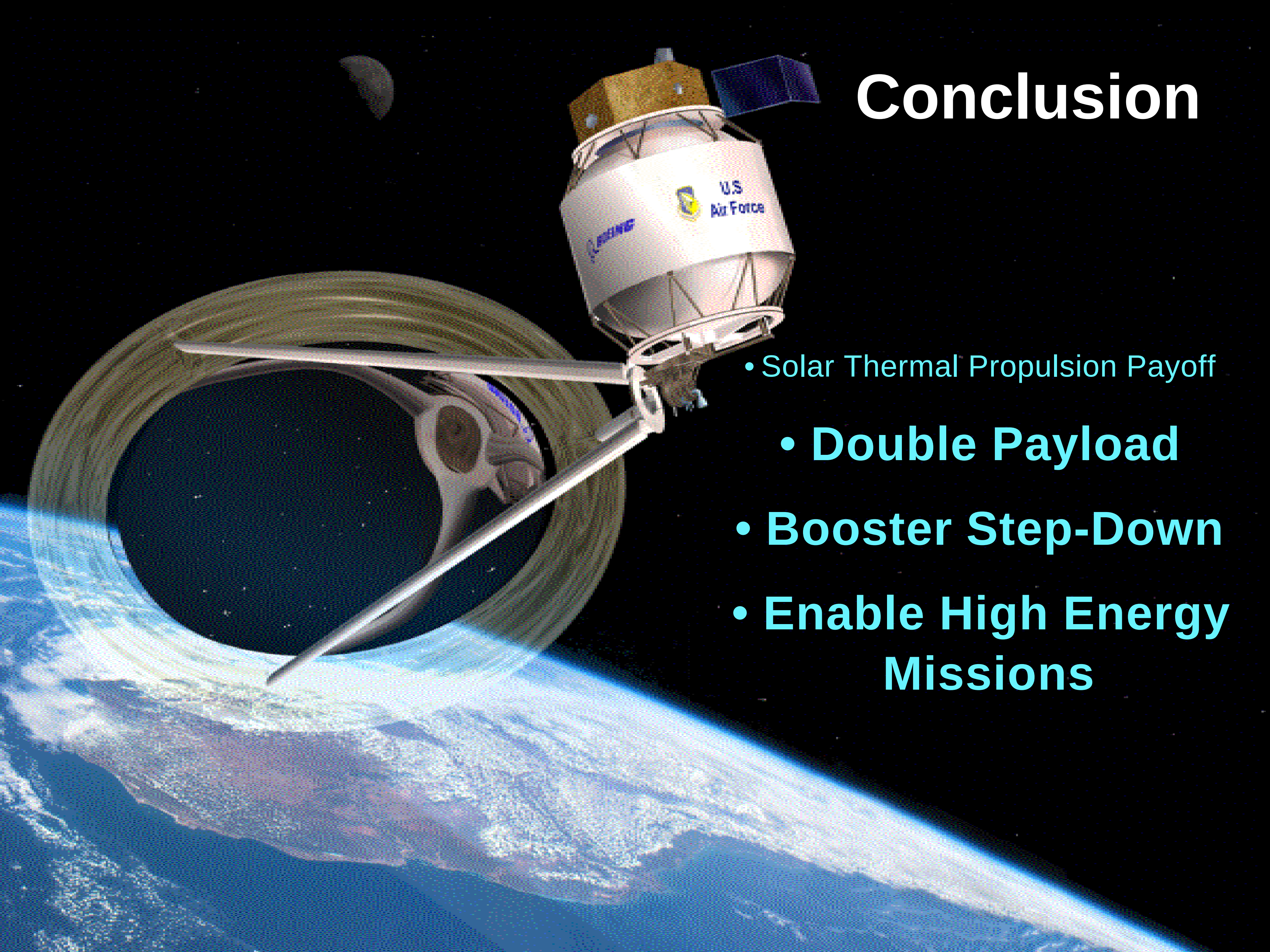
Efficiencies and Mass Properties can be traded!

Delta II w 2.4 lbf Solar OTV Payload vs Trip Time



Phase III has potential of doubling PL to GEO

Conclusion



- Solar Thermal Propulsion Payoff

- **Double Payload**
- **Booster Step-Down**
- **Enable High Energy Missions**